

ENGINEERING **RESEARCH** REVIEW 2019



SOUTH DAKOTA STATE UNIVERSITY

Office of Engineering Research



Dear Colleagues,

Once again, I have the pleasure of providing a synopsis of the research activities taking place in the past year in the Jerome J. Lohr College of Engineering. Ideally, I would guide you on a tour of our college's extensive laboratory facilities and show you firsthand some of the projects on which our faculty and students are working. Since that is not possible, we will do so through text and photos.

Over the past year, we have been working closely with the Research Park at SDSU to develop industrial research with local and regional companies. Dwaine Chapel, CEO and executive director of the Research Park, and I have paid many visits to area industries to learn more about their research needs. This has been a fascinating activity on its own as we learn more about the modeling and simulation, manufacturing and materials needs close to home.

Because of these efforts, we are focusing a major portion of this annual publication on three startup companies and one regional precision agriculture company to highlight some of the partnerships our college and researchers have developed. Many other partnerships are in the initial development stages and are in queue for future stories. In all cases, the skills of our faculty and students make it possible to initiate these relationships. You will see several quotes in this publication highlighting the people aspect, which is a huge advantage of working in South Dakota.

This issue also features two research groups. One group consists of a team of young faculty who focus on improving our nation's ability to take advantage of alternative energy, while the other is the college's oldest research lab and calibrates optical remote sensing imaging satellites.

The college's power systems research group consists of faculty in electrical and mechanical engineering, as well as mathematics and statistics. They aim to break down barriers that prevent widespread use of renewable energy. South Dakota is a prime state for both wind and solar energy generation, so this work fits well with state priorities. The group's work spans system simulations, voltage and frequency control, peak demand reduction and hardware-in-the-loop experimentation.

In contrast, the oldest research lab in the college is our image processing lab, founded in 1990 to support USGS EROS and NASA. This team focuses on radiometric, geometric and spatial characterization, calibration and correction of satellite and airborne optical imagery. Three full-time staff members and up to 12 students make up the lab team. Known internationally for their expertise in radiometric calibration, this group has worked with satellite imaging systems from all over the world.

It has been another fruitful year here at SDSU and in the Lohr College of Engineering. The dedication and skills of our faculty, staff and students have made it possible. If your company would like to interact with us, do not hesitate to pick up the phone and give us a call!

Dennis Helder, Ph.D.

Associate Dean for Research

Distinguished Professor of Electrical Engineering

ENGINEERING RESEARCH REVIEW 2019



About the cover

This test bed allows SDSU researchers to analyze how a sprayer system performs. Six researchers from three departments are working with Shane Swedlund of the Raven Applied Technology Division to do computer modeling of agricultural sprayer nozzles and then verify their results using the test bed they developed (See story page 6).

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Helder recounts journey **building world-class** image processing laboratory

When it comes to calibrating satellite images, Dennis Helder is one of the world's experts. The distinguished professor of electrical engineering and associate dean for engineering research began working on satellite imagery more than 30 years ago and built one of the world's leading satellite calibration laboratories.

The South Dakota State University Imaging Processing Laboratory, which opened in 1990, is one of three university labs in the nation doing radiometric satellite calibration. Helder and his team specialize in calibration using vegetative surfaces, while the University of Arizona focuses on desert targets and Rochester Institute of Technology on thermal sensing.

Signals from satellite sensors produce digital images composed of pixels. Each pixel measures the amount of energy

reflected or emitted from Earth, Helder explained. When those images are calibrated, they become datasets.

The SDSU laboratory also leads the world in using remote sites that do not change over time to calibrate satellite images.

"In contrast, the work we do changes over time," said Helder, who retired June 21. Those changes are evident as Helder describes his journey from doctoral student to imaging lab director. During his career, Helder secured more than \$25 million in federal, state and private research funding.

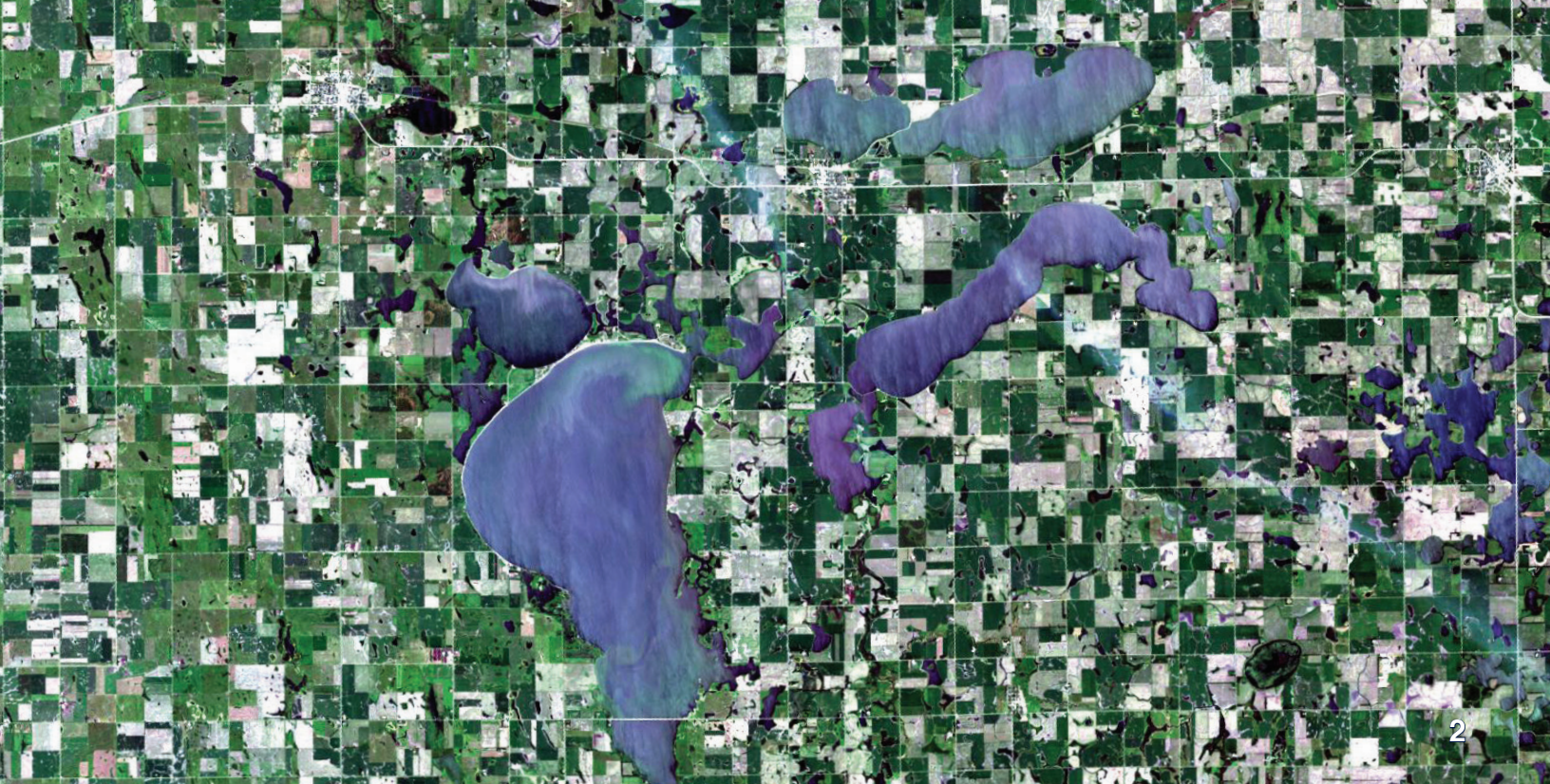
Destriping satellite images

When Helder was finishing his doctorate at North Dakota State University, his search for a dissertation project led him to the U.S. Geological Survey Earth Resources Observation and

Science Center. The Landsat 5 Thematic Mapper had begun dropping lines, creating stripes on the images. "People around the world had not been able to correct it," said June Thormodsgard, EROS image mapping and research development section leader at the time.

Once Helder had devised an algorithm to solve the Landsat 5 striping problem, EROS had other projects for him to tackle.

While completing his dissertation work, Helder, then an assistant professor, secured about \$1,300 in state funding to buy a workstation. "At the time, PCs were not capable of working with imagery," he said. The funds allowed him to purchase a Sun workstation that had a 24-bit color display. "There was nothing like it on campus—that was a major step forward in terms of the capacity to do things."



1. Distinguished Professor Dennis Helder, center, who began the SDSU Image Processing Laboratory in 1990, visits with imaging engineers Larry Leigh, left, and Morakot Kaewmanee during a March staff meeting. Leigh became lab director in June when Helder retired. Kaewmanee is an expert on pseudo-invariant calibration sites.

2. This is a satellite image of Kingsbury County from July 13, 2013. Each pixel measures the amount of energy reflected or emitted from the Earth. When these images are calibrated, they become datasets that scientists can use to examine changes occurring on the Earth's surface.

3. In August 2010, Leigh, left, and Helder, right, were part of an international field campaign that evaluated Tuz Gölü, one of the world's largest salt lakes, as a pseudo-invariant calibration site.

The next EROS project was destriping images from the first in the series of French high-resolution optical satellites known as SPOT—Satellite Pour l'Observation de la Terre.

"Landsat had a whiskbroom scanner, but SPOT had a pushbroom scanner," he recalled. "Pushbroom scanning is like a copy machine with rows of detectors scanning as the satellite orbits the Earth—it was really stripy."

He and graduate student Michael Choate each came up with a solution, but Helder admitted, "Mike's method worked better. It decomposed the images into different components via a new method utilizing wavelets." Since completing his master's degree, Choate has been at EROS, first as a government contractor and, more recently, as a USGS computer engineer.

Calibrating satellite images

The EROS projects continued for several years until Helder learned that what EROS really needed was a radiometry expert. "I didn't really want to do that, but a wise man once said, 'go where the money is,' so I started doing radiometry," he recalled. "Geometry is making sure that each pixel is in the right place, but radiometry is making sure the energy measurement is right. If it's wrong, a green cornfield could turn out purplish."

In 1992, Helder received a NASA fellowship to spend the summer at the Goddard Space Center in Greenbelt,

Maryland. He worked 10 weeks on a high-resolution imaging instrument slated for Landsat 7. "The instrument never flew," he said, but during the last week, he spent one day with NASA scientist John Barker outlining a plan to calibrate Landsat 5 images. "I spent the next 10 years working step-by-step through the plan—artifact correction, single orbit calibration, cold focal plane calibration and then lifetime calibration," he said.

"That was huge—now we had a relationship with NASA and USGS EROS," he noted. "We were a diversified lab. Our eggs were no longer in one basket."

In addition, thanks to an unexpected meeting invitation from then-department head Lewis Brown, Helder secured NSF Experimental Program to Stimulate Competitive Research funding to buy a set of workstations. "I bought five computers, one big one in terms of capacity and four others that were terminals, and had the resources to hire five students to work in the lab," he said. "We had a 200-megahertz computer and a 9-gigabit hard drive. We thought we had the world by the tail."

Measuring blur

That infrastructure and workforce led Helder to do research on atmospheric point-spread functions, a measure of how blurry an image is. "We developed ways to measure the blur introduced by the atmosphere," he explained.

In the late 1990s, Helder presented



this research at NASA's Stennis Space Center in Mississippi. "NASA was developing a commercial remote sensing program and more private companies were putting satellites in space," Helder said. "I ended up getting funding to measure the quality of imaging on commercial high-resolution remote sensing satellites."

For several summers beginning in 2000, a dozen students deployed eight 20-by-20-meter black, white and blue tarps, weighing close to 100 pounds each, and 20 1-meter convex mirrors on a field in southeast Brookings. "It took two hours to set up the tarps before a satellite went over," he said. "You've never enjoyed the South Dakota wind until you've deployed tarps—it was quite an undertaking."

By 2005, that funding disappeared. However, Helder noted, "we were pretty well diversified."

Helder received research funding as a member of the Landsat 7 Science Team, with the earth-imaging satellite launching in 1999. He then also worked on Earth Observing-1, one of NASA's pathfinder satellites, testing new imaging technologies for future Landsat satellites.

When Barker retired from the Goddard Space Center in 2007, Darrel Williams, head of the Goddard Earth Science Division, awarded Barker's NASA calibration funding to the SDSU Image Processing Lab. "That was a tremendous vote of confidence in the work we were doing," Helder said. That also meant more than \$400,000 a year in research funding.

Beginning in 2008, Helder served on the Landsat 8 Science Team—and was at Vandenberg Air Force Base in California for the Feb. 11, 2013, Landsat 8 launch.

Developing calibration sites

Before a satellite is launched, the sensors are calibrated to an absolute radiometric standard. However, while in orbit after launch, the sensors drift or change, Helder explained.

One method of measuring that change is vicarious calibration. A ground crew takes measurements at the same time the satellite passes over a location.

To take into account the light lost when it passes through the atmosphere, the crew runs their location measurements through an atmospheric model called MODTRAN to predict what the sensors should see when a satellite passes overhead. From these readings, the engineers can adjust the calibration.

Another satellite calibration approach uses pseudo-invariant calibration sites to calibrate satellite sensors. PICS are remote places, such as a desert or dry salt lakebed, where the surface properties—and therefore the reflectance—do not change over time. The stability of these sites eliminates the need to revisit the site each time the satellite sensors are calibrated.

"This approach is less expensive because you don't have to put a team in the field or do a lot of data processing from the field team's measurements," Helder pointed out.

Going beyond Landsat

During the last five years, the imaging lab has offered its calibration expertise to government and commercial agencies around the world.

"We decided the things we learned to do well through our research for NASA and EROS could be of service to others that want their instruments calibrated," Helder said. "We have worked with virtually all the commercial satellite people in our country as well as many international agencies."



The imaging lab has done sensor calibration for Planet Labs, DigitalGlobe, the German RapidEye constellation and the United Kingdom's Surrey Satellite Technology Ltd. In addition, the group has calibrated sensors on satellites from Thailand, Brazil, China, France, Kazakhstan and India.

The lab has become a world leader in PICS and has been working closely with a French government calibration group to set the standards for PICS, according to Helder. SDSU imaging engineer Morakot Kaewmanee is "the leading person on what you can do with PICS these days."

Larry Leigh, who succeeded Helder as director, has found new PICS via a global search made possible through a partnership with Google Earth Engine. In addition, he and his team are finding locations that are ideally suited to calibrating specific spectral bands.

Looking to the future

The lab's survival depends on "being creative and coming up with new ways of doing things," Helder said.

"PICS have historically been small, around tens of kilometers in size," Helder said. "SDSU engineers are expanding those PICS to cover thousands of kilometers—and the initial results are good. It's a huge advantage to be able to image over a broad region and do multiple calibrations in short time periods."

Furthermore, Helder noted, "For decades, we have calibrated sensors at the top of the atmosphere, but users want to know what's going on at the surface—among the trees, forests and cropland." Consequently, EROS and other entities are developing and distributing surface products.


However, surface reflectance measurements are available at only a few locations. "How can you validate a surface product over the hot, humid Florida Panhandle if you don't have a measurement there?" Helder said. "A major next step is to figure out how to do surface reflectance product validation."

But those challenges will be ones that Leigh and the team will need to address and Helder is optimistic about their ability to do so. "As I watch these young people (in the lab), they are coming up with good ideas. I am very happy with what I see."

1. In August 2010, Distinguished Professor Dennis Helder, far left, and imaging engineer Larry Leigh, far right, were part of a team of scientists from 10 nations who assessed Tuz Gölü as a pseudo-invariant calibration site.

2. Leigh measures the reflectance of the sand at all slopes and orientations at the Algodones Dunes in southeastern California in March 2015. After the initial readings are taken, the team can use this PICS to calibrate sensors without revisiting the site.

3. This satellite image shows Tuz Gölü, a salt lake in central Turkey, which is used as a PICS.



Engineering intern Brian Prchal, who is also an SDSU mechanical engineering student, left, and senior mechanical design engineer Travis Burgers of Raven Industries install nozzle control valves on the sprayer test bed.

Researchers build test bed to verify sprayer nozzle simulations

An initiative to connect businesses, such as Raven Industries, with engineering researchers whose skillsets can help address specific industry initiatives, is gaining traction.

Six researchers from three departments are working with Shane Swedlund, engineering manager for the Raven Applied Technology Division, to do computer modeling of agricultural sprayer nozzles and to construct a test bed to verify the modeling results.

“There are a lot of variables related to chemical application,” Swedlund said. “If we can make sure the right amount of product goes in the right parts of the field, we can be more efficient with chemical usage and more efficient with passes through the field, which can help save time, reduce soil compaction and improve fuel utilization.”

Last summer, assistant professor Jeffrey Doom of the Department of Mechanical Engineering, who has done simulations and experimental work on fuel nozzles, began using computational fluid dynamics software to simulate the sprayer nozzles. That preliminary work led to a one-year collaborative project in which Raven provided funding for SDSU researchers to develop a test bed for the sprayer nozzles. Work began in February.

“I am anticipating that we will grow this project,” Swedlund said. “We will learn things working with Dr. Doom and the team, and there will be other areas we will be able to identify.”

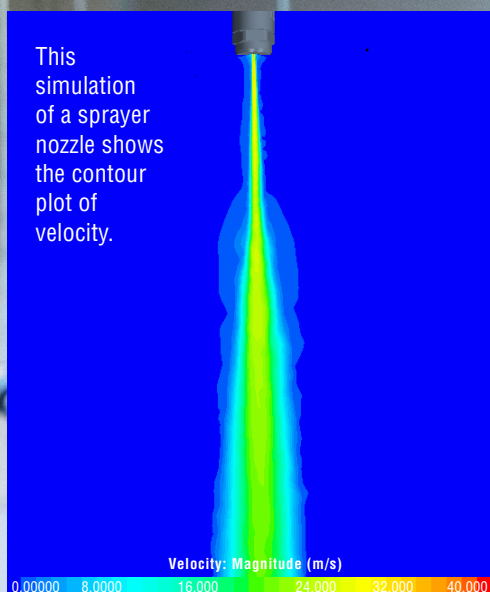
Doom is in charge of the spray nozzle simulation and test bed development. Assistant professors Marco Ciarcià and Kim-Doang Nguyen of the Department of Mechanical Engineering will work on the control system. Associate professor Matthew Biesecker of the Department of Mathematics and Statistics will do the statistical analyses.

On the electrical engineering side, assistant professor Zhen Ni is the machine learning and artificial intelligence expert and professor Qiquan Qiao will be in charge of sensors.

Using test bed

The test bed allows researchers to analyze how a sprayer system performs. Six nozzles in the test bed will be able to move up and down as well as left and right. A high-speed camera will capture slow-motion footage of the rapidly pulsing sprayer nozzles.

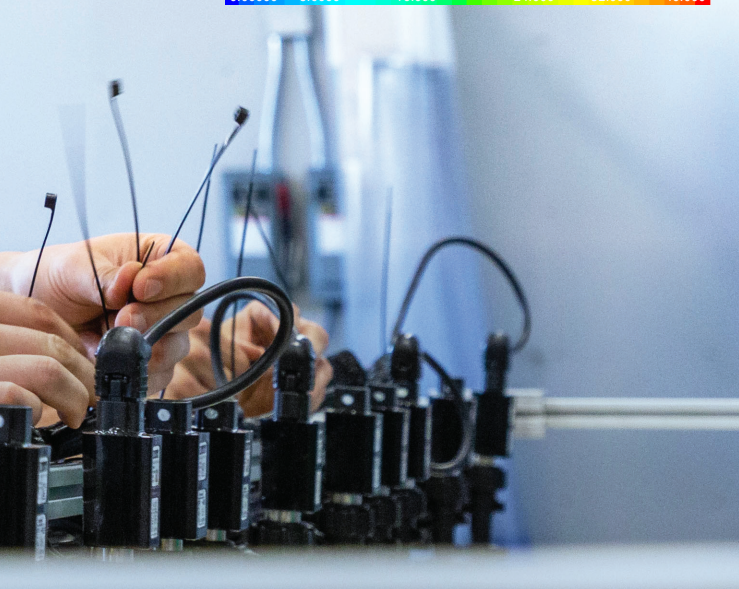
“This first-generation test bed was built so it can be taken apart,” Doom said. The water tray can be replaced with a spray patternator, which measures liquid distribution using individual channels and beakers.



Jeffrey Doom

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Senior Ryan Fouts captures high-speed video of the pulsating nozzles on the sprayer test bed.

Graduate student Ibrahim Alsayed, who is working on the sprayer nozzle simulation, and senior Ryan Fouts assembled the test bed.

Swedlund said, “First, we will be verifying that the spray system is doing what we think it is doing, what it is designed to do. Using the test bed, we can accurately determine what’s happening at the nozzles.” Increasing that level of understanding will help Raven improve its Hawkeye Precision Application System.

Due to safety concerns, the liquid used in the test bed will be water. “For most of the fluids, the carrier is water and the agent is a very small percentage,” Doom said. “We will learn a lot just sticking with water, then we can easily change the viscosity of the liquid and even change the substance as a function of temperature in the simulation.”

Once the researchers get what Doom called “a good understanding of the experimental work,” they will couple that with the nozzle simulations.

Building simulations

The researchers will first look at how pressure, velocity and angle influence the spray pattern. “The spray distribution has to be uniform,” Doom pointed out. “The idea is to minimize the amount of agent used while maximizing coverage.”

Doom and Alsayed are using STAR CCM+®, ANSYS Fluent and OpenFOAM® software to model a variety of sprayer nozzles. They began with a simple nozzle model before tackling more complex models, such as those for pulse and air induction nozzles.

In future work, Doom wants to be able to model droplet size and droplet distribution. Through a literature search, the SDSU team found that another research group has successfully used computer modeling of a nozzle to predict drift based on variables such as water droplet size.

“This will be a challenging research project for Raven and SDSU, but we have talented students and a new high-performance computing cluster known as Roaring Thunder that will help with future work,” Doom said.

“Using the simulations, we will be able to speed product development cycle time to make spray application better for growers,” said Raven’s Swedlund.

Doom added, “This is an excellent example of the potential that exists when researchers collaborate with regional businesses.”



Data scientists evaluate credit risk to help lenders, borrowers

To lend or not to lend, that is the question.

With the increase in online lending, financial service companies face the daunting task of determining which consumers will repay their loans and, more importantly, which will not.

Traditionally, the risk was determined based solely on credit history. However, ValidiFI, a Florida-based company, provides lending companies an alternative means of evaluating risk, in part, through predictive modeling expertise from the South Dakota State University Department of Mathematics and Statistics.

"We help financial service companies make better decisions when providing a financial product to a consumer," explained ValidiFI Chief Operating Officer Jesse Berger. "We are a few years into it and already working with some of the largest personal lenders in the nation."

Using vast amounts of complex data to detect patterns can help lenders determine which applicants will repay loans—and it's one of the strengths of the South Dakota State data science program, explained associate professor Tom Brandenburg.

When the two met in 2016, Berger was interested in recruiting data scientists to work in Florida. Brandenburg suggested opening an office in the Research Park at South Dakota State University—and that's what Berger did.

As ValidiFI's chief data scientist, Brandenburg mentors data scientists who are also SDSU alumni at the Brookings office, which opened last year.

Providing unique decision-making data

Data science has dramatically improved financial technology and is vital to providing access to more consumers. As financial services migrate to the digital realm, the possibility for risk is greater and more sophisticated.

"Many consumers want to do their banking online. In the virtual world, we no longer sit across the table from a client. Consequently, there are more opportunities for fraud," said Berger, who described himself as a serial entrepreneur. During the last 25 years, he has started multiple companies that provide data or technology services.



Characteristic Analysis

$$\text{Shift in Score} = (\text{Actuals}_i - \text{Expected}_i) \cdot \text{Points}_i$$

Actuals_i = the actual percent of the population for group i .

Expected_i = the expected percent of the population for group i .

Points_i = the associated scorecard points for group i .

Population Index
 $\frac{(R\%)}{(E\%)}$
groups current
population to



CEO Oscar DiVeroli, center, visited the Brookings ValidiFI office in the Research Park at SDSU. Pictured with him are, from left, data scientists Basanta Chalise and Nikhil Pamidimukkala, chief data scientist Tom Brandenburger, an associate professor in the SDSU Department of Mathematics and Statistics; and data scientist Audrey Bunge.

Tom Brandenburger

Associate Professor

Department of Mathematics and Statistics

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“What’s unique is the type of data we provide for the credit decision-making and underwriting,” explained Berger, who started Merchant Boost about four years ago. The firm was recently renamed ValidiFI. “We spent years building out the technology and went to market nearly two years ago.”

“We are using alternative data to verify that people who are taking out loans are who they say they are and that they are a decent credit risk,” Brandenburger said. “It’s data that credit bureaus do not have—and it’s helping people demonstrate they are good payers and weeding out the bad players who are purposefully trying to defraud the lender.”

For instance, he explained, “If the name, Social Security number and birthdate do not match the data provided by the applicant, our bank account validation product concludes that person is not likely to repay a personal loan.” The same is true, for example, if a single address is listed on 37 applications for credit in the last seven days or if that address has 72 different people associated with it during the last 60 days.

The bank account validation product also “confirms ownership of bank accounts and debit cards to reduce or even eliminate some of the fraud that is happening,” Berger said.

Though Brandenburger describes predictive modeling as “a fancy version of math that established likelihood out of a

large amount of data,” he also admits the difficulty lies in the complexity and the size of the data.

“Tom and his group in Brookings use machine learning and artificial intelligence to build different types of scores to help make sense of the data,” Berger said.

The payment instrument risk score, for instance, analyzes a variety of financial datasets to generate a risk score that places the applicant in a low, medium or high credit risk category. “We send the results in real time within milliseconds, giving the financial institution the score and details about the person based on the data we have,” Berger noted.

Minimizing overdraft charges

ValidiFI’s bank aggregation technology monitors a borrower’s bank account. By explicitly authorizing this type of oversight, the borrower not only secures a loan, likely at a more reasonable rate, but also receives protection against a bounced or late payment—and in the end, a better credit rating.

Many people don’t realize that bounced payments hurt both the lender and the borrower. “When you bounce a payment, you get an overdraft—but so do lending companies that use ACH (automated clearing house) payments,” Brandenburger explained.

“We can alert the lender ahead of time if the bank account balance is running low and if there is a high probability the client

will not make the next payment,” Berger continued. The parties can then work out arrangements to avoid an overdraft. “This helps both the borrower and the lender.”

This is particularly beneficial for a client with little to no credit history—and something that young people find worthwhile, Brandenburger said. “It’s a generational thing—young people are happy to give to get. We are creating an environment with a safety net for everyone involved that reduces the risk associated with these monetary transactions.”

Expanding services

Through a partnership with First Bank and Trust of Brookings, ValidiFI will be offering a new service line for credit card and ACH payments.

“Essentially, we will provide a data solution to verify identity, detect fraud and determine credit-worthiness based on payment instruments like credit cards and bank accounts, Berger said. The new service line builds on the company’s core payment data instrument.

The payments will be processed through the company’s relationship with First Bank & Trust. “It’s exciting to partner with such an innovative company, as ValidiFI’s products and proven results are a real game changer in the lending industry,” said Cal DeJong, the bank’s president of national products.

Berger hopes to enter the mortgage, automobile and home loans markets.

Associate Professor Tom Brandenburger, left, discusses a population stability metric, similar to a process control chart for manufacturing, with data scientists Audrey Bunge and Basanta Chalise. Both are SDSU alumni. Bunge, a Rapid City native, completed her bachelor’s degree in mathematics and data science in December 2018 and is working on her master’s degree in data science. Chalise, who is from Nepal, completed his master’s degree in data science in May.

Team develops sensor to monitor blood sugar through breath



A simple puff into a handheld device may be all it takes for people with diabetes to monitor their blood sugar using a new technology developed through Nano Tek LLC.

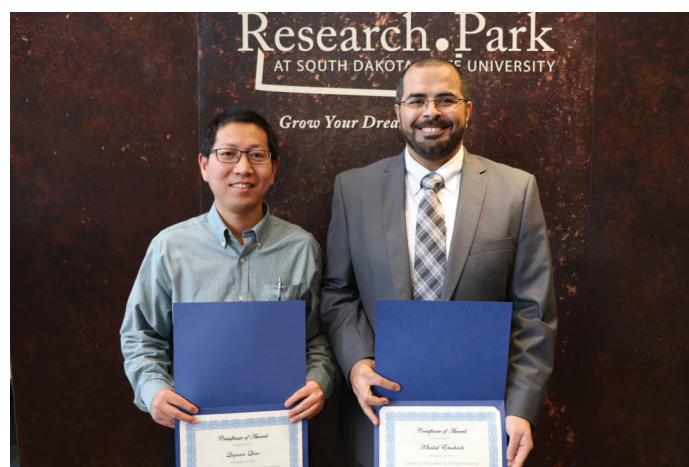
“The device will not only be painless, but reusable—no finger pricks or expensive tests,” explained doctoral student Khalid Emshadi. He did research on drug-delivery systems while earning a master’s degree in materials science and biomedical engineering from Washington State University.

The sensor device will work like a breathalyzer, but rather than measuring alcohol, the sensor measures acetone in a person’s breath to determine blood sugar level, according to Qiquan Qiao, Harold C. Hohbach Endowed Professor of Electrical Engineering. He and Emshadi co-founded Nano Tek LLC with assistance from Dwaine Chapel, CEO and executive director of the Research Park at South Dakota State University.

“Acetone is a biomarker for blood glucose,” said doctoral student Md Tawabur Rahman, who leads sensor development. The researchers submitted an invention disclosure to the SDSU Office of Technology Transfer and Commercialization.

Developing biosensor

Qiao, along with Professor Huitian Lu of the Department of Construction and Operations Management, began developing the sensor in 2015 through a two-year grant from South Dakota Board of Regents Research and Innovation Grant Program and Sanford Health.



Professor Qiquan Qiao, left, and doctoral student Khalid Emshadi of the SDSU Department of Electrical Engineering and Computer Science won the STEM division of the Center for Innovation and Entrepreneurship Idea Competition, sponsored by the SDSU Department of Economics and supported by the SDSU Division of Research and Economic Development. The sensor device measures acetone to determine an individual’s blood glucose level.

To make the biosensor, the researchers used a technique called molecular imprinting to deposit a polymer layer onto graphene. “The 3D polymer has small cavities that are the same shape and size as acetone molecules,” Rahman said. “It works like a filter, allowing only acetone to get through and bind to the graphene.”

“Exhaled human breath contains more than 3,000 volatile organic compounds resulting from the body’s metabolic pathways,” Emshadi said. “The sensor detects only acetone and ignores the others. The selectivity is very high.”

When the acetone molecules attach to graphene, it changes the material’s electrical properties.

“The resistance in the graphene sensing layer changes based on the concentration of acetone gas,” said Rahman. The sensor detects acetone levels ranging from 0.9 parts per million to 10 parts per million.

The acetone concentrations in the breath of a nondiabetic range from 0.3 to 0.9 ppm. However, in diabetics, those levels are higher, Rahman said. To test the sensor, he placed it in a chamber into which different concentrations of acetone gas were introduced. Additional electronic components will then convert the measurement to milligrams per deciliter, the standard blood glucometer reading.

Rahman will also optimize the sensor’s recovery time—how long the user must wait before taking another reading. “My goal is to make it less than one minute,” he said. Qiao estimates that completing the proof-of-concept work will take approximately nine months.

Once preliminary evaluations are completed, the researchers will integrate the sensor into a prototype device that can be tested using human breath.

Moving toward commercialization

With Chapel’s assistance, Qiao and Emshadi secured a \$20,389 grant from the South Dakota Governor’s Office of Economic Development Economic Development Administration i6 fund to gather more data on the sensor and help build a prototype. The EDA i6 program, which is part of the South Dakota Bioscience Commercialization Alliance, is a proof-of-concept program that helps move bioscience innovations to the market.

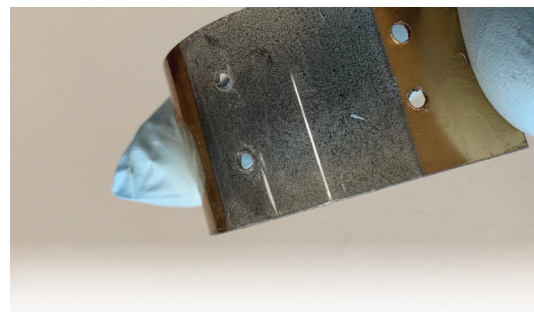
In addition, Qiao and Emshadi worked with Chapel as their industry mentor to obtain a \$50,000 National Science Foundation Innovation Corps grant to explore their customer base and build connections with health-care professionals and biomedical manufacturers. The NSF I-Corps™ program provides training for scientists and

engineers to extend their research beyond the laboratory.

At the January I-Corps™ training session, Emshadi said, “We met with 100-plus customers, as well as companies, medical advisers and doctors. We found there is a need for such a noninvasive device. This technology will increase the compliance rate among diabetics, which will save money for insurance companies because patients will experience fewer complications, such as kidney failure.”

Qiao and Emshadi also identified companies interested in their technology and will continue developing those relationships. “Once we finish the proof of concept, we can work together to improve the product,” Qiao said.

Emshadi envisions putting the breath sensor into a smartphone along with an app that enables users to effectively monitor and manage their blood glucose levels. “This new technology promises to be revolutionary—it will make life easier for everyone with diabetes,” he said.



This flexible sensor could hold the key to diabetics one day monitoring their blood sugar with a simple puff into a handheld device. The technology is being developed by South Dakota State University researchers through Nano Tek LLC.



Doctoral student Md Tawabur Rahman, left, and professor Qiquan Qiao prepare to use direct current sputtering to deposit a thin layer of gold onto the sensor.



Cybersecurity startup finds supportive business climate, student talent



Three years ago, Silicon Valley entrepreneur Dhiraj Sharan decided to start a company to help midsize to large companies protect themselves from cybersecurity threats. What he did not know then was that he would open his new business in Brookings, South Dakota.

That same year, his wife, Anamika Prasad, accepted a position as an assistant professor in the South Dakota State University Department of Mechanical Engineering. “It turned out to be a blessing in disguise,” said Sharan, who started Query.AI in the Research Park at South Dakota State University last year.

“Cybersecurity threats can come from scammers, competitors, intellectual property thieves or rogue nations—all these are in the national headlines,” said Sharan, who has worked in the enterprise information technology and cybersecurity space for the past 20 years. He also holds 10 patents in cybersecurity and IT data analytics.

“Those kinds of threats have always been there, but now they are harder to detect. Now companies have to use advanced data analytics and AI techniques to continuously monitor their IT environment,” he said.

“When I came to know about the state’s focus on cybersecurity and the programs at South Dakota State University and Dakota State University, I saw there is talent here we can leverage. What has been missing from this ecosystem is the cybersecurity industry,” he said.

Strong support for entrepreneurs

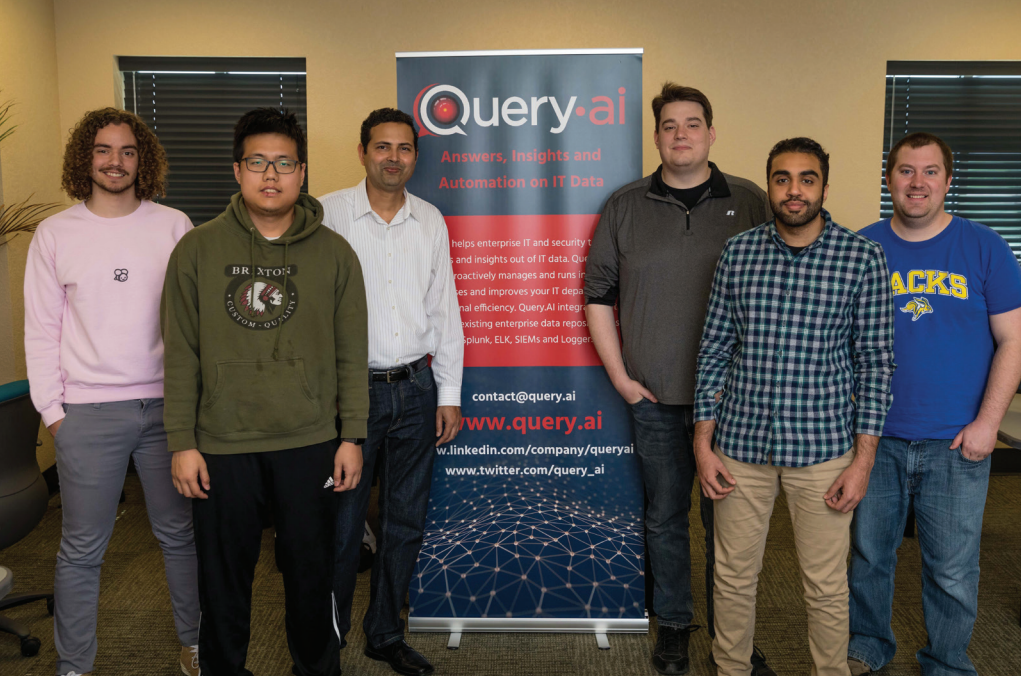
“The entrepreneurial culture, talent pool and local can-do attitude made launching Query.AI highly efficient and cost-effective,” Sharan said of the strong local and state support he found for entrepreneurs.

Early on, he met Dwaine Chapel, Research Park CEO and executive director. Chapel helped Sharan make connections at the Governor’s Office of Economic Development as well as the Brookings Innovation Center.

“He was an early believer who saw the opportunity the same way I did. He provided a lot of support and introductions,” Sharan said.

Chapel and Enterprise Institute Executive Director Tim Weelborg also introduced Sharan to angel investor groups. Though he began raising

Strong local and state support for entrepreneurs and a pool of talented computer science students led Silicon Valley entrepreneur Dhiraj Sharan to start Query.AI in the Research Park at South Dakota State.



Four senior SDSU computer science interns and a full-time computer scientist who is an SDSU alumnus work with Query.AI founder Dhiraj Sharan. They are, from left, interns Ferdinand Ramos of South Shore; and Minxuan Sun of Guangzhou, China; Sharan; customer success engineer Craig Jorgensen, originally of Tyler, Minnesota; and interns Mahmood Alnasser of Al-Ahsa, Saudi Arabia; and Mark Kirschenman of Huxley, Iowa. In addition, the company has two interns from Dakota State University in Madison and a team of senior engineers working remotely in Bangalore, India.

venture capital in Silicon Valley first, Sharan said, “Query.AI capital funding is split equally between Silicon Valley and here.”

Black Hills Regional Angel Fund in Rapid City, Falls Angel Fund in Sioux Falls, Hub City Capital LLC in Aberdeen and Park Capital Fund LLC are among the company’s South Dakota investors.

Through the GOED, Sharan also received support from the Dakota Seeds Program, which provides matching funds for interns, and the Proof of Concept Fund, which supports research to demonstrate the feasibility of innovations on the path to commercialization.

“I feel being in South Dakota is a great advantage,” Sharan explained, citing lower operating costs. He also sees being “centered between two coasts in the Central time zone” as advantageous.

In addition to tapping into the student workforce, Sharan uses faculty expertise in artificial intelligence and machine learning with assistant professor Semhar Michael of the Department of Mathematics and Statistics serving as an adviser. To fulfill the need for experienced senior engineers and professionals, Query.AI also has an engineering team in Bangalore, the Silicon Valley of India.

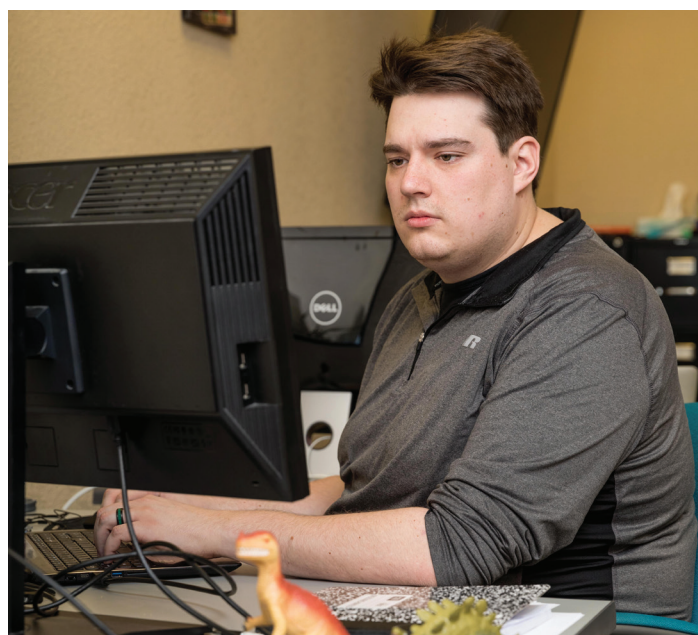
Benefits of SDSU connection

Query.AI sponsors senior design projects at SDSU as a means of not only connecting with students and faculty, but also collaborating with the campus IT group, Sharan noted. Vice President of Security and Technology Mike Adelaine and his team built a central security operations center to monitor the South Dakota Board of Regents and Regents Information Systems’ cybersecurity data. The regental institutions face approximately 20 million cyberattacks each day.

This spring, Query.AI student intern Craig Jorgensen, who is now a full-time employee, was part of a three-member senior design team that worked with the SDSU security team.

“We came up with an open-source solution that allows them to access more data more easily to get the answers and insights they can use to help stop phishing and other potential attacks on the university,” Jorgensen said.

The relationship with SDSU also benefits the company. “We can test our solution in a friendly home environment, and they (the security team) can leverage it for their use cases,” Sharan said.



After a one-year internship, Craig Jorgensen, who earned a bachelor’s degree in computer science from SDSU in May 2018, is now a full-time employee at Query.AI. After learning about security analytics, Jorgensen said, “I realized how important the work we are doing here is, and I developed an interest and a passion for it.”

In addition to Jorgensen, four interns from SDSU and two from DSU work at Query.AI.

“For students graduating in computer science, we want to be the company where they come for internships first,” Sharan said. The demand for cybersecurity professionals is increasing dramatically with an estimated 3.5 million shortfall in the workforce worldwide by 2021. “This can be a springboard to a very nice career.”

Sharan’s new business has garnered local and state recognition. Query.AI received the 2018 Company of the Year Award from the Brookings Innovation Center and placed second in the 2019 Governor’s Giant Vision Competition.



Power systems researchers help integrate renewable energy into electric grid

Three power systems researchers in the Department of Electrical Engineering and Computer Science are addressing challenges associated with integrating renewable energy into the electric power grid.

“Our big mission is to remove barriers from interconnecting renewables—solar panels and wind turbines—in the grid,” said associate professor Reinaldo Tonkoski, whose research focuses on voltage and frequency control. Assistant professor Tim Hansen works on balancing residential energy demand with system conditions using smart home technologies, while assistant professor Zhen Ni specializes in machine learning and control systems for smart grids.

Tonkoski and Hansen are part of a team led by the University of Alaska Fairbanks that received a two-year U.S. Department of Energy Established Program to Simulate Competitive Research Implementation Grant this summer. This is the first DOE grant for

these researchers and will bring approximately \$600,000 in funding to SDSU.

“We are networking to design the grid of the future, one that is environmentally, economically and socially sustainable,” Tonkoski said. Those priorities are helping them build connections with DOE national laboratories.

In 2018, renewable energy accounted for 70% of South Dakota’s net energy generation—46% from hydroelectric power and 24% from wind energy, according to the U.S. Energy Information Administration. Integrating renewable energy into the grid is both a regional and a national priority.

Simulating power systems

“A lot of the research we do involves simulation and modeling of power systems—that requires powerful computers,” Tonkoski explained. He leads the team of SDSU researchers that secured a \$252,362 National Science Foundation Major Research

Left: Doctoral students Aravind Ingalalli, left, and Shuva Paul, work in the microgrid lab on the third floor of Daktronics Engineering Hall. This summer, Paul is doing an internship with the power group at the National Renewable Energy Laboratory in Golden, Colorado.

Right Top: Master's student Kapil Duwadi adjusts the control of solar energy output to regulate the voltage of the power grid. This summer, Duwadi began a full-time position as a researcher-II in the Electrical Power Distribution Systems Group at the National Renewable Energy Laboratory in Golden, Colorado.

Right Bottom: Doctoral student Fernando Dos Reis, left, and assistant professor Tim Hansen adjust settings on the new real-time digital simulator. In January, Dos Reis began an eight-month internship in the Electricity Infrastructure Group at Pacific Northwest National Laboratory in Richland, Washington, working on transactive energy.



Instrumentation grant, which when combined with department and college funding allowed them to purchase an OPAL-RT Technologies real-time digital simulator for \$360,000. Other team members are Hansen, Ni, assistant professor Semhar Michael of the Department of Mathematics and Statistics, and assistant professor Jeffrey Doom of the Department of Mechanical Engineering.

“We are one of the first universities to have such a powerful simulation tool,” said Tonkoski. This acquisition and the university’s new high-performance computing cluster make the power system group’s simulation capabilities well aligned with national labs working on similar grid integration projects.

The real-time digital simulator allows researchers to emulate batteries and renewable energy generation and to see how different energy management strategies affect the electrical grid at different scales. The digital simulator has power amplifiers that can simulate wind turbines or solar panels, or even connect to the photovoltaic system on the Daktronics Engineering Hall roof.

Researchers can simulate interconnected solar panels to compare inverters that convert the panels’ direct current output into alternating current for the grid. “The field programmable gate array can run simulations in time steps of nanoseconds for a year. I can run tests in parallel or one at a time under the same conditions,” Tonkoski said. “That is not possible in a real situation.”

Controlling voltage, frequency

One of the challenges of integrating renewable energy is how to support and control voltage and frequency in the power grid. “The power system is always regulating how much energy is being generated with how much is being consumed. Maintaining that balance ensures everybody receives good quality electricity,” Tonkoski said. An unbalanced system can result in blackouts.

“Renewable energy is variable by nature and adds complexity to normal grid operation. The smart grid provides data integration to optimize their use and to balance power consumption,” he continued. The power systems group designs algorithms to create frequency support for the grid.

When it comes to balancing the system, Tonkoski said, “Renewables are one of the fastest sources to respond to variations in power because there are no rotating masses. If the load drops too fast, I can quickly ramp down solar and wind to try to adjust the system dynamically.”

Tim Hansen

Assistant Professor

Department of
Electrical Engineering and
Computer Science

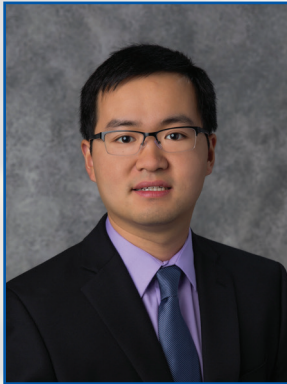
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In addition, he noted, “There are moments in the Midwest when the cost of energy is negative because we have a surplus.” That’s when energy storage systems could play a key role in not only balancing the system but also decreasing energy costs.

In spring 2020, Tonkoski will continue research begun this summer with the energy storage program at Sandia National Laboratory, which is developing new technologies to scale battery systems. “This group specializes in control systems and market analysis,” he said.

Sandia researchers have developed tools to analyze the technical and economic viability of energy storage systems and renewables. Tonkoski looks forward to learning these new methodologies and, hopefully, creating opportunities for future DOE projects.

With that goal in mind, Hansen and Tonkoski will examine how a battery energy storage system can help address variability and improve frequency stability through a seed grant from the SDSU Research Scholarship and Creative Activity Challenge Fund.

Reducing peak demand

Hansen uses high-performance computing to simulate how consumer use of smart home technologies can help reduce electricity use during peak times. “Hundreds of processing elements running in parallel reduce computational time,” Hansen pointed out.

Utility companies pay less for nonpeak energy because more efficient generators, including renewables, such as wind and solar, are in use. “Peak power generators are the most expensive to run and are, hypothetically, the most emission-intensive units,” Hansen said. By altering consumers’ energy usage habits, peak power demand can be reduced—and a portion of the money utility companies save can be passed on to their customers.

Through a three-year NSF project, Hansen is working with Colorado State University researchers to evaluate how an end-user distribution plan can balance residential electricity demand. Using algorithms, the researchers determine when and how much energy must be shifted to balance the energy draw in a representative community of 5,555 houses equipped with smart technologies. Two doctoral students work on the project, with one of the students doing an internship at Pacific Northwest National Laboratory this summer based on the project results.

This type of research aligns with work being done at the national laboratories, noted Hansen, who interned at the National Renewable Energy Laboratory in Golden, Colorado, while completing his doctorate at Colorado State. Two SDSU electrical engineering graduate students interned at NREL this summer and three who earned their master’s degrees this spring have landed full-time jobs there.

For a South Dakota-based project, Ni and Hansen developed a residential energy management system in partnership with Sioux Valley Energy of Colman through funding from the South Dakota Board of Regents. Ni created optimization algorithms to minimize energy costs for utility companies and a multilevel reward system for customers who shift energy usage to nonpeak times. Hansen used simulation to test the system’s effectiveness. The project resulted in two invention disclosures and the two graduate students who worked on the project are now employed full-time at NREL.

In addition, Ni is working on a proof-of-concept study developing machine learning-based algorithms to perform real-time processing of power grid data through the SDSU Research Scholarship and Creative Activity Challenge Fund. This will help the power systems researchers generate baseline data to apply for further DOE funding.

“We are strategically well positioned to support the power industry on the state and national level,” Tonkoski concluded.

AWARDS

Engineering researchers receive college, university awards



Reinaldo Tonkoski

Associate Professor

Department of Electrical Engineering
and Computer Science

Reinaldo.Tonkoski@sdstate.edu

Tonkoski named outstanding engineering researcher

Designing the power grid of the future means figuring out how to integrate renewable energy generated from wind turbines and solar panels. With that end in mind, associate professor Reinaldo Tonkoski of the Department of Electrical Engineering and Computer Science led a team of researchers that secured National Science Foundation funding to purchase a state-of-the-art, real-time digital simulator.

This acquisition and the university's new high-performance computing cluster make the power system group's simulation capabilities well aligned with U.S. Department of Energy national labs working on grid integration (see story, pages 14-16).

This summer, Tonkoski received a two-year U.S. Department of Energy Grant as part of a research team led by the University of Alaska

Fairbanks. The grant will provide approximately \$600,000 in research funding to SDSU.

For his work, Tonkoski was named the Jerome J. Lohr College of Engineering's outstanding researcher at the university's Faculty Celebration of Excellence this spring. His research focuses on grid integration of renewable energy and voltage and frequency control of power systems.

Next spring, he will be on sabbatical to continue work he began this summer on energy storage systems at Sandia National Laboratory, which is developing new technologies to utility scale battery systems. He will be learning new methods of analyzing the technical and economic viability of energy storage systems and renewable energy for voltage and frequency control of power systems.



Rouzbeh Ghabchi

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Ghabchi receives Young Investigator Award

Research aimed at making asphalt pavements last longer has earned assistant professor Rouzbeh Ghabchi of the Department of Civil and Environmental Engineering the Jerome J. Lohr College of Engineering's 2019 Young Investigator Award.

Ghabchi, who came to SDSU in 2016, has been updating and rebuilding the department's transportation infrastructure materials research capabilities. He works with the South Dakota Department of Transportation to align his materials research with state priorities.

Through funding from the Mountain Plains Consortium, Ghabchi determined the optimum application rates for three types of tack coats and evaluated how the freeze-thaw cycle impacts tack coat effectiveness and pavement durability.

For another MPC project, Ghabchi evaluated the effect of moisture-induced damage on South Dakota asphalt mixes and made

recommendations regarding which types of aggregate mineralogy work best with specific binders and additives available in the state. The project also covered the effects of moisture, aging and oxidation on adhesion properties of asphalt binders with different types of aggregates containing warm mix asphalt additive, reclaimed asphalt pavement and antistripping agent.

Currently, Ghabchi is investigating whether adding forestry byproducts, specifically cellulose nanofibers, to asphalt binder can increase the ductility and fatigue life of asphalt pavements. The project, done in collaboration with the SDSU Department of Mechanical Engineering, is funded by the North Central Regional Sun Grant Center.



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Grantwinship Awards



Faculty members in the Jerome J. Lohr College of Engineering who secured or had research expenditures of \$100,000 or more during the 2018 fiscal year are—front row, from left, Reinaldo Tonkoski, Suzette Burckhard, Mostafa Tazarv, Qiquan Qiao, Larry Leigh, Semhar Michael and Gregory DeRynck; second row, Francis Ting, Nadim Wehbe, Cedric Neumann, Tom Brandenburger and Chris Schmit; back row, Dennis Helder, Chris Saunders, Rouzbeh Ghabchi, Rich Reid, Greg Vavra and Stephen Gent. Not pictured is Junwon Seo.